

Eurocode 7 — Geotechnical design —

Part 2: Ground investigation and testing

ICS 91.010.30; 93.020

National foreword

This British Standard is the UK implementation of EN 1997-2:2007, incorporating corrigendum June 2010. It supersedes DD ENV 1997-2:2000 and DD ENV 1997-3:2000 which are withdrawn. It partially supersedes BS 5930:1999 and BS 1377-9:1990.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by CEN corrigendum June 2010 is indicated in the text by AC1 AC1.

The structural Eurocodes are divided into packages by grouping Eurocodes for each of the main materials: concrete, steel, composite concrete and steel, timber, masonry and aluminium; this is to enable a common date of withdrawal (DOW) for all the relevant parts that are needed for a particular design. The conflicting national standards will be withdrawn at the end of the coexistence period, after all the EN Eurocodes of a package are available.

Following publication of the EN, there is a period allowed for national calibration during which the National Annex is issued, followed by a coexistence period of a maximum three years. During the coexistence period Member States are encouraged to adapt their national provisions. At the end of this coexistence period, the conflicting parts of national standard(s) will be withdrawn.

In the UK, the primary corresponding national standard is:

- BS 5930:1999, *Code of practice for site investigations*

and based on this transition period, this standard will be withdrawn/revised on a date to be announced, but at the latest by March 2010.

For in-situ testing, the primary test method references in BS EN 1997-2:2007 are to new CEN/ISO standards and this will require the withdrawal of some sections of BS 1377-9:1990, *Methods of test for soils for civil engineering purposes* — In-situ tests, as well as parts of BS 5930:1999 as they are published.

For laboratory testing, many of the primary test method references in BS EN 1997-2:2007 are new CEN/ISO technical specifications. These will not be adopted in the UK and the standards below will continue to be the preferred standards.

- BS 1377-1:1990, *Methods of test for soils for civil engineering purposes – General requirements and sample preparation*
- BS 1377-2:1990, *Methods of test for soils for civil engineering purposes – Classification tests*

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Amendments/corrigenda issued since publication

Date	Comments
31 October 2010	Implementation of CEN corrigendum June 2010

- BS 1377-3:1990, *Methods of test for soils for civil engineering purposes – Chemical and electro-chemical tests*
- BS 1377-4:1990, *Methods of test for soils for civil engineering purposes – Compaction-related tests*
- BS 1377-5:1990, *Methods of test for soils for civil engineering purposes – Compressibility, permeability and durability tests*
- BS 1377-6:1990, *Methods of test for soils for civil engineering purposes – Consolidation and permeability tests in hydraulic cells and with pore pressure measurement*
- BS 1377-7:1990, *Methods of test for soils for civil engineering purposes – Shear strength tests (total stress)*
- BS 1377-8:1990, *Methods of test for soils for civil engineering purposes – Shear strength tests (effective stress)*

Further guidance will be given in the National Annex to EN 1997-2.

The UK participation in its preparation was entrusted to Technical Committee B/526, Geotechnics.

A list of organizations represented on this committee can be obtained on request to its secretary.

Where a normative part of this EN allows for a choice to be made at the national level, the range and possible choice will be given in the normative text, and a note will qualify it as a Nationally Determined Parameter (NDP). NDPs can be a specific value for a factor, a specific level or class, a particular method or a particular application rule if several are proposed in the EN.

To enable EN 1997-2 to be used in the UK, the NDPs will be published in a National Annex, which will be made available by BSI in due course, after public consultation has taken place.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

English Version

Eurocode 7 - Geotechnical design - Part 2: Ground investigation and testing

Eurocode 7 - Calcul géotechnique - Partie 2:
Reconnaissance des terrains et essais

Eurocode 7 - Entwurf, Berechnung und Bemessung in der
Geotechnik - Teil 2: Erkundung und Untersuchung des
Baugrunds

This European Standard was approved by CEN on 12 June 2006.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



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Contents	Page
Foreword	7
Section 1 General.....	10
1.1 Scope	10
1.1.1 Scope of Eurocode 7	10
1.1.2 Scope of EN 1997-2.....	10
1.2 Normative references.....	11
1.3 Assumptions	12
1.4 Distinction between Principles and Application Rules	12
1.5 Definitions	13
1.5.1 Terms common to all Eurocodes	13
1.5.2 Terms common to Eurocode 7.....	13
1.5.3 Specific definitions used in EN 1997-2	13
1.6 Test results and derived values	14
1.7 The link between EN 1997-1 and EN 1997-2	15
1.8 Symbols and Units	16
Section 2 Planning of ground investigations	20
2.1 Objectives	20
2.1.1 General.....	20
2.1.2 Ground	21
2.1.3 Construction materials	22
2.1.4 Groundwater	22
2.2 Sequence of ground investigations	22
2.3 Preliminary investigations	23
2.4 Design investigations.....	24
2.4.1 Field investigations	24
2.4.2 Laboratory tests.....	27
2.5 Controlling and monitoring	31
Section 3 Soil and rock sampling and groundwater measurements.....	33
3.1 General.....	33
3.2 Sampling by drilling	33
3.3 Sampling by excavation.....	33
3.4 Soil sampling	33
3.4.1 Categories of sampling methods and laboratory quality classes of samples	33
3.4.2 Soil identification.....	34
3.4.3 Planning of soil sampling.....	34
3.4.4 Handling, transport and storing of samples	35
3.5 Rock sampling	35
3.5.1 Categories of sampling methods.....	35
3.5.2 Rock identification.....	36
3.5.3 Planning of rock sampling	36
3.5.4 Handling, transport and storing of samples	37
3.6 Groundwater measurements in soils and rocks	37
3.6.1 General.....	37
3.6.2 Planning and execution of the measurements	37
3.6.3 Evaluation of results of groundwater measurements	38

Section 4 Field tests in soil and rock	40
4.1 General.....	40
4.2 General requirements.....	40
4.2.1 Planning a specific test programme	40
4.2.2 Execution	41
4.2.3 Evaluation	41
4.3 Cone penetration and piezocone penetration tests (CPT, CPTU, CPTM).....	42
4.3.1 Objectives	42
4.3.2 Specific requirements.....	42
4.3.3 Evaluation of test results	43
4.3.4 Use of test results and derived values	43
4.4 Pressuremeter tests (PMT).....	45
4.4.1 Objectives	45
4.4.2 Specific requirements.....	45
4.4.3 Evaluation of test results	46
4.4.4 Use of test results and derived values	47
4.5 Flexible dilatometer test (FDT)	48
4.5.1 Objectives	48
4.5.2 Specific requirements.....	48
4.5.3 Evaluation of test results	48
4.5.4 Use of test results and derived values	49
4.6 Standard penetration test (SPT).....	49
4.6.1 Objectives	49
4.6.2 Specific requirements.....	49
4.6.3 Evaluation of test results	49
4.6.4 Use of test results and derived values	50
4.7 Dynamic probing tests (DP)	51
4.7.1 Objectives	51
4.7.2 Specific requirements.....	52
4.7.3 Evaluation of test results	52
4.7.4 Use of test results and derived values	52
4.8 Weight sounding test (WST)	53
4.8.1 Objectives	53
4.8.2 Specific requirements.....	53
4.8.3 Evaluation of test results	54
4.8.4 Use of test results and derived values	54
4.9 Field vane test (FVT).....	55
4.9.1 Objectives	55
4.9.2 Specific requirements.....	55
4.9.3 Evaluation of test results	55
4.9.4 Use of test results and derived values	55
4.10 Flat dilatometer test (DMT).....	56
4.10.1 Objectives	56
4.10.2 Specific requirements.....	56
4.10.3 Evaluation of test results	56
4.10.4 Use of test results and derived values	57
4.11 Plate loading test (PLT)	57
4.11.1 Objectives	57
4.11.2 Specific requirements.....	58
4.11.3 Evaluation of test results	58
4.11.4 Use of test results and derived values	58

Section 5 Laboratory tests on soil and rock	60
5.1 General.....	60
5.2 General requirements for laboratory tests	60
5.2.1.General requirements	60
5.2.2 Procedures, equipment and presentation.....	60
5.2.3 Evaluation of test results	60
5.3 Preparation of soil specimens for testing	61
5.3.1 Objective	61
5.3.2 Requirements	61
5.4 Preparation of rock specimens for testing	62
5.4.1 Objective	62
5.4.2 Requirements	62
5.5 Tests for classification, identification and description of soil	63
5.5.1 General.....	63
5.5.2 Requirements for all classification tests	63
5.5.3 Water content determination.....	63
5.5.4 Bulk density determination	64
5.5.5 Particle density determination.....	64
5.5.6 Particle size analysis	64
5.5.7 Consistency limits determination.....	65
5.5.8 Determination of the density index of granular soil	66
5.5.9 Soil dispersibility determination	67
5.5.10 Frost susceptibility	68
5.6 Chemical testing of soil and groundwater	68
5.6.1 Requirements for all chemical tests	68
5.6.2 Organic content determination.....	70
5.6.3 Carbonate content determination	71
5.6.4 Sulfate content determination	71
5.6.5 pH value determination (acidity and alkalinity)	72
5.6.6 Chloride content determination.....	72
5.7 Strength index testing of soil	73
5.7.1 Objective	73
5.7.2 Requirements	73
5.7.3 Use of test results	73
5.8 Strength testing of soil.....	73
5.8.1 Objective and scope	73
5.8.2 General requirements	74
5.8.3 Evaluation and use of test results.....	75
5.8.4 Unconfined compression test.....	75
5.8.5 Unconsolidated, undrained triaxial compression test	76
5.8.6 Consolidated triaxial compression test	76
5.8.7 Consolidated direct shear box tests.....	77
5.9 Compressibility and deformation testing of soil.....	78
5.9.1 General.....	78
5.9.2 Oedometer compressibility testing	78
5.9.3 Triaxial deformability testing	80
5.10 Compaction testing of soil.....	81
5.10.1 Scope.....	81
5.10.2 Compaction tests.....	81
5.10.3 California Bearing ratio (CBR) test	81

5.11 Permeability testing of soil	82
5.11.1 Objective	82
5.11.2 Requirements	82
5.11.3 Evaluation and use of test results	83
5.12 Tests for classification of rocks	84
5.12.1 General	84
5.12.2 Requirements for all classification tests	84
5.12.3 Rock identification and description	84
5.12.4 Water content determination	85
5.12.5 Density and porosity determination	86
5.13 Swelling testing of rock material	86
5.13.1 General	86
5.13.2 General requirements	87
5.13.3 Evaluation of test results	87
5.13.4 Swelling pressure index under zero volume change	87
5.13.5 Swelling strain index for radially-confined specimens with axial surcharge	88
5.13.6 Swelling strain developed in unconfined rock specimen	89
5.14 Strength testing of rock material	89
5.14.1 General	89
5.14.2 Requirements for all strength tests	89
5.14.3 Evaluation of test results	90
5.14.4 Uniaxial compression and deformability test	90
5.14.5 Point load test	91
5.14.6 Direct shear test	92
5.14.7 Brazil test	93
5.14.8 Triaxial compression test	94
Section 6 Ground investigation report	95
6.1 General requirements	95
6.2 Presentation of geotechnical information	95
6.3 Evaluation of geotechnical information	96
6.4 Establishment of derived values	97
Annex A (informative) List of test results of geotechnical test standards	98
Annex B (informative) Planning of geotechnical investigations	101
Annex C (informative) Example of groundwater pressure derivations based on a model and long term measurements	109
Annex D (informative) Cone and piezocone penetration tests	111
Annex E (informative) Pressure meter test	121
Annex F (informative) Standard penetration test	125
Annex G (informative) Dynamic probing test	129
Annex H (informative) Weight sounding test	132
Annex I (informative) Field vane test	133
Annex J (informative) Flat dilatometer test Example of correlations between E_{OED} and DMT results	138
Annex K (informative) Plate loading test	139
Annex L (informative) Detailed information on preparation of soil specimens for testing	143
Annex M (informative) Detailed information on tests for classification, identification and description of soil	150
Annex N (informative) Detailed information on chemical testing of soil	157

Annex O	(informative) Detailed information on strength index testing of soil	162
Annex P	(informative) Detailed information on strength testing of soil.....	163
Annex Q	(informative) Detailed information on compressibility testing of soil.....	165
Annex R	(informative) Detailed information on compaction testing of soil	166
Annex S	(informative) Detailed information on permeability testing of soil	168
Annex T	(informative) Preparation of specimen for testing on rockmaterial.....	170
Annex U	(informative) Classification testing of rock material	171
Annex V	(informative) Swelling testing of rock material	173
Annex W	(informative) Strength testing of rock material	175
Annex X	(informative) Bibliography	180

Foreword

This document (EN 1997-2: 2007) has been prepared by Technical Committee CEN/TC 250 "Structural Eurocodes", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2007, and conflicting national standards shall be withdrawn at the latest by March 2010.

This document supersedes ENV 1997-2:1999 and ENV 1997-3:1999.

CEN/TC 250 is responsible for all Structural Eurocodes.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Portugal, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Background of the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonization of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works, which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980s.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement¹ between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links *de facto* the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990	Eurocode :	Basis of Structural Design
EN 1991	Eurocode 1:	Actions on structures

¹ Agreement between the Commission of the European Communities and the European Committee for Standardization (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

EN 1992	Eurocode 2:	Design of concrete structures
EN 1993	Eurocode 3:	Design of steel structures
EN 1994	Eurocode 4:	Design of composite steel and concrete structures
EN 1995	Eurocode 5:	Design of timber structures
EN 1996	Eurocode 6:	Design of masonry structures
EN 1997	Eurocode 7:	Geotechnical design
EN 1998	Eurocode 8:	Design of structures for earthquake resistance
EN 1999	Eurocode 9:	Design of aluminium structures

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes:

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 – Mechanical resistance and stability – and Essential Requirement N°2 – Safety in case of fire;
- as a basis for specifying contracts for construction works and related engineering services;
- as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs).

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents² referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards³. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

² According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

³ According to Art. 12 of the CPD the interpretative documents shall :

- a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;
- b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc. ;
- c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex.

The National annex may only contain information on those parameters, which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e.:

- values and/or classes where alternatives are given in the Eurocode;
- values to be used where a symbol only is given in the Eurocode;
- country specific data (geographical, climatic), *e.g.* snow map;
- the procedure to be used where alternative procedures are given in the Eurocode.

It may also contain:

- decisions on the application of informative annexes;
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and harmonised technical specifications (ENs and ETAs) for products

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works⁴. Furthermore, all the information accompanying the CE Marking of the construction products, which refer to Eurocodes, should clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific to Eurocode 7

EN 1997-2 gives guidance for the planning and interpretation of geotechnical laboratory and field tests that are used for the support of geotechnical design of buildings and civil engineering works.

EN 1997-2 is intended for clients, designers, geotechnical laboratories, field testing laboratories and public authorities.

EN 1997-2 is intended to be used with EN 1997-1.

When using EN 1997-2, particular regard should be paid to the underlying assumptions and conditions given in 1.3.

The six sections of EN 1997-2 are complemented by 24 informative annexes.

National annex for EN 1997-2

The national standard implementing EN 1997-2 should have a national annex containing all information concerning the application of EN 1997-2 in the relevant country.

⁴ See Art.3.3 and Art.12 of the CPD, as well as 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

Section 1 General

1.1 Scope

1.1.1 Scope of Eurocode 7

- (1) EN 1997 is intended to be used in conjunction with EN 1990:2002, which establishes the principles and requirements for safety and serviceability, describes the basis of design and verification and gives guidelines for related aspects of structural reliability.
- (2) EN 1997 is intended to be applied to the geotechnical aspects of the design of buildings and civil engineering works. It is subdivided into various separate parts (see 1.1.2).
- (3) EN 1997 is concerned with the requirements for strength, stability, serviceability and durability of structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.
- (4) Numerical values of actions on buildings and civil engineering works to be taken into account in design are provided in EN 1991 for the various types of construction. Actions imposed by the ground, such as earth pressures, shall be calculated according to the rules of EN 1997.
- (5) Separate European Standards are intended to be used to treat matters of execution and workmanship. They are denoted in the relevant sections.
- (6) In EN 1997 execution is covered to the extent that is necessary to conform to the assumptions of the design rules.
- (7) EN 1997 does not cover the special requirements of seismic design. EN 1998 provides additional rules for geotechnical seismic design, which complete or adapt the rules of this standard.

1.1.2 Scope of EN 1997-2

- (1) EN 1997-2 is intended to be used in conjunction with EN 1997-1 and provides rules supplementary to EN 1997-1 related to:
- planning and reporting of ground investigations;
 - general requirements for a number of commonly used laboratory and field tests;
 - interpretation and evaluation of test results;
 - derivation of values of geotechnical parameters and coefficients.

In addition, examples of the application of field test results to design are given.

NOTE Establishment of characteristic values is covered in EN 1997-1.

- (2) This document gives no specific provisions for environmental ground investigations.
- (3) Only commonly used geotechnical laboratory and field tests are covered in this standard. These were selected on the basis of their importance in geotechnical practice, availability in

commercial geotechnical laboratories and existence of an accepted testing procedure in Europe. The laboratory tests on soils are mainly applicable to saturated soils.

NOTE It is expected that updates of the present standard will gradually include laboratory and field tests covering additional aspects of soil and rock behaviour.

(4) The provisions of this standard apply primarily to projects of geotechnical category 2, as defined in 2.1 of EN 1997-1:2004. The ground investigation requirements for category 1 projects are normally limited as the verifications often will be based on local experience. For geotechnical category 3 projects, the amount of investigations required will normally be at least the same as indicated for geotechnical category 2 projects in the following sections. Additional investigations and more advanced tests, related to the circumstances that place a project in geotechnical category 3, may be necessary.

(5) The derivation of parameter values is dedicated primarily to the design of pile and spread foundations based on field testing, as detailed in Annexes D, E, F and G of EN 1997-1:2004.

1.2 Normative references

(1) The following normative documents contain provisions which, through reference in this text, constitute provisions of this European Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this European Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the last edition of the normative document referred to applies.

EN 1990:2002	<i>Eurocode — Basis of structural design</i>
EN 1997-1:2004	<i>Eurocode 7 — Geotechnical design — Part 1: General rules</i>
EN ISO 14688-1	<i>Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description</i>
EN ISO 14688-2	<i>Geotechnical investigation and testing — Identification and classification of soil — Part 2: Classification principles</i>
EN ISO 14689-1	<i>Geotechnical investigation and testing — Identification and classification of rock - Part 1: Identification and description</i>
EN ISO 22475-1 ⁵	<i>Geotechnical investigation and testing — Sampling by drilling and excavation and groundwater measurements — Part 1: Technical principles of execution</i>
[AC1] EN ISO 22476-1 ⁵	<i>Geotechnical investigation and testing — Field testing — Part 1: Electrical cone and piezocone penetration tests [AC1]</i>
EN ISO 22476-2	<i>Geotechnical investigation and testing — Field testing — Part 2: Dynamic probing</i>
EN ISO 22476-3	<i>Geotechnical investigation and testing — Field testing — Part 3: Standard penetration test</i>
EN ISO 22476-4 ⁵	<i>Geotechnical investigation and testing — Field testing — Part 4: Ménard pressuremeter test</i>
EN ISO 22476-5 ⁵	<i>Geotechnical investigation and testing — Field testing — Part 5: Flexible dilatometer test</i>
EN ISO 22476-6 ⁶	<i>Geotechnical investigation and testing — Field testing — Part 6: Self boring pressuremeter test</i>
[AC1] EN ISO 22476-7 ⁶	<i>Geotechnical investigation and testing — Field testing — Part 7: Borehole jack test [AC1]</i>

⁵ to be published

[AC1] ⁶ to be published **[AC1]**

EN ISO 22476-8 ⁶	<i>Geotechnical investigation and testing — Field testing — Part 8: Full displacement pressuremeter test</i>
EN ISO 22476-9 ⁶	<i>Geotechnical investigation and testing — Field testing — Part 9: Field vane test</i>
AC1 EN ISO 22476-12	<i>Geotechnical investigation and testing — Field testing — Part 12: Mechanical CPT AC1</i>
EN ISO 22476-13 ⁶	<i>Geotechnical investigation and testing — Field testing — Part 13: Plate loading test</i>

NOTE The Bibliography presents a number of CEN ISO Technical Specifications (CEN ISO/TS), giving information on procedures, equipment, evaluation and presentation for some field and laboratory tests. These technical specifications may become European/ISO standards in due time. The National Standards Body may decide to keep its national standard in force during the lifetime of a CEN ISO/TS. National Annexes to EN 1997-2 may give information regarding national practise involved.

1.3 Assumptions

- (1) Reference is made to - EN 1990:2002, 1.3 and EN 1997-1:2004, 1.3.
- (2) The provisions of this standard are based on the assumptions given below:
 - data required for design are collected, recorded and interpreted by appropriately qualified personnel;
 - structures are designed by appropriately qualified and experienced personnel;
 - adequate continuity and communication exist between the personnel involved in data-collection, design and construction;

1.4 Distinction between Principles and Application Rules

- (1) Depending on the character of the individual clauses, distinction is made in EN 1997-2 between Principles and Application Rules.
- (2) The Principles comprise:
 - general statements and definitions for which there is no alternative;
 - requirements and analytical models for which no alternative is permitted unless specifically stated.
- (3) The Principles are preceded by the letter P.
- (4) The Application Rules are examples of generally recognised rules which follow the Principles and satisfy their requirements.
- (5) It is permissible to use alternatives to the Application Rules given in this standard, provided it is shown that the alternative rules accord with the relevant Principles and are at least equivalent with regard to the structural safety, serviceability and durability, which would be expected when using the Eurocodes.

NOTE If an alternative design rule is submitted for an application rule, the resulting design cannot be claimed to be wholly in accordance with EN 1997-2, although the design will remain in accordance with the Principles of EN 1997-1. When EN 1997-2 is used in respect of a property listed in an Annex Z of a product standard or an ETAG, the use of an alternative design rule may not be acceptable for CE marking.

(6) In EN 1997-2, the Application Rules are identified by a number in brackets e.g. as in this clause.

1.5 Definitions

1.5.1 Terms common to all Eurocodes

(1)P The terms used in common for all Eurocodes are defined in EN 1990.

1.5.2 Terms common to Eurocode 7

(1)P The terms specific to EN 1997 are defined in 1.5.2 of EN 1997-1:2004.

1.5.3 Specific definitions used in EN 1997-2

1.5.3.1

derived value

value of a geotechnical parameters obtained from test results by theory, correlation or empiricism (see 1.6)

1.5.3.2

disturbed sample

sample where the soil structure, water content and/or constituents have been changed during sampling

1.5.3.3

measured value

value that is measured in a test

1.5.3.4

natural specimen

specimen made from the available (disturbed, undisturbed, remoulded) sample

1.5.3.5

quality class

classification by which the quality of a soil sample is assessed in the laboratory

NOTE For laboratory testing purposes, soil samples are classified in five quality classes (see 3.4.1).

1.5.3.6

remoulded sample

sample of which the soil or rock structure is fully disturbed

1.5.3.7

remoulded specimen

fully disturbed specimen, at natural water content

1.5.3.8

re-compacted specimen

specimen forced into a mould with a rammer or under desired static stress state

1.5.3.9

reconstituted specimen

specimen prepared in the laboratory; for fine soils, it is prepared as a slurry (at or above the liquid limit) and then consolidated (sedimented); for coarse soils, it is either poured or pluviated in dry (dried) or wet conditions and compacted, or consolidated

1.5.3.10

re-consolidated specimen

specimen compressed in a mould or cell under static pressure while allowing drainage to take place

1.5.3.11

sample

portion of soil or rock recovered from the ground by sampling techniques

1.5.3.12

specimen

part of a soil or rock sample used for a laboratory test

1.5.3.13

strength index test

test of a nature that yields an indication of the shear strength, without necessarily giving a representative value

NOTE The results of such a test are subject to uncertainty.

1.5.3.14

swelling

expansion due to reduction of effective stress resulting from either reduction of total stress or absorption of (in general) water at constant total stress

NOTE Swelling includes the reverse of both compression and consolidation.

1.5.3.15

undisturbed sample

sample where no change in the soil characteristics of practical significance has occurred

1.6 Test results and derived values

(1) Test results and derived values form the basis for the selection of characteristic values of ground properties to be used for the design of geotechnical structures, in accordance with 2.4.3 of EN 1997-1:2004.

NOTE 1 The process of geotechnical design consists of a few successive phases (see Figure 1.1), the first of which covers the site investigation and testing, whereas the next one is devoted to the determination of characteristic values, and the last phase covers the design verification calculations. Rules for the first phase are given in the

present standard. The determination of characteristic values and the design of the structures are covered by EN 1997-1.

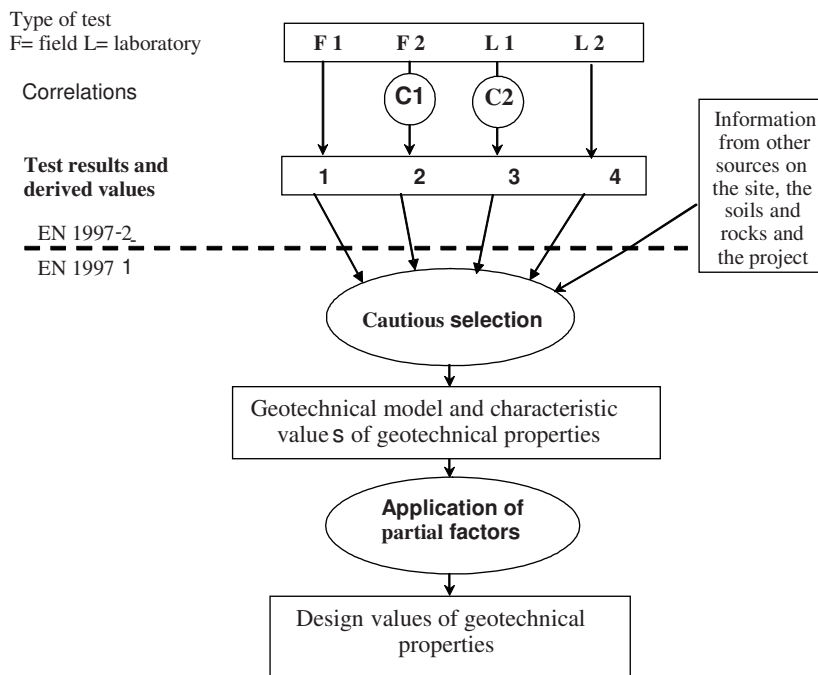


Figure 1.1 — General framework for the selection of derived values of geotechnical properties

AC1 (2) Test results can be experimental curves or values of geotechnical parameters. In Annex A, a list of test results is given to serve as a reference to test standards⁷. **AC1**

(3) Derived values of geotechnical parameters and/or coefficients, are obtained from test results by theory, correlation or empiricism.

NOTE 2 The examples of correlations used to determine derived values given in the annexes to Section 4 of this standard are obtained from the literature. These correlations may correlate the value of a geotechnical parameter or coefficient with a test result, such as the q_c -value of a CPT. They may also connect a geotechnical parameter to a test result by means of theoretical considerations (for example, when deriving a value of the angle of shearing resistance ϕ' from pressuremeter test results or from the index of plasticity).

NOTE 3 In certain cases, the derivation of geotechnical parameters by means of a correlation is not made before the determination of the characteristic value, but after the test results have been corrected or transformed into conservative estimates.

1.7 The link between EN 1997-1 and EN 1997-2

(1) Figure 1.2 presents the general architecture of the CEN standards related to geotechnical engineering problems and those directly linked to EN 1997. The design part is covered by EN 1997-1. The present standard gives rules for ground investigations and obtaining geotechnical parameters or coefficients values to be used for determining the characteristic values (as specified in EN 1997-1). It gives also informative examples of calculation methods for spread and deep foundations. The implementation of EN 1997 needs information based on other standards, in particular those related to ground investigations and to the execution of geotechnical works.

⁷ Geotechnical test standards, yielding these results are prepared by CEN/TC341.

EN 1997-1

Design rules

- General framework for geotechnical design
- Definition of ground parameters
- Characteristic and design values
- General rules for site investigation
- Rules for the design of main types of geotechnical structures
- Some assumptions on execution procedures

EN 1997-2

Geotechnical investigation and testing

- Detailed rules for site investigations
- General test specifications
- Derivation of ground properties and geotechnical model of the site
- Examples of calculation methods based on field and laboratory tests

Test standards (CEN/TC 341)

Standards for

- Drilling and sampling methods and groundwater measurements
- Laboratory and field tests on soils and rocks
- Tests on structures or parts of structures
- Identification and classification of soils and rocks

Execution of geotechnical works (CEN/TC 288)

Execution standards

- specific design rules (informative annexes)
- specific test procedures

Figure 1.2 — General architecture of the CEN standards linked with EN 1997

1.8 Symbols and units

(1) For the purpose of EN 1997-2 the following symbols apply.

NOTE The notation of the symbols used is based on ISO 3898:1997.

Latin letters

C_c	compression index
c'	cohesion intercept in terms of effective stress
c_{fv}	undrained shear strength from the field vane test
c_u	undrained shear strength
C_s	swelling index
c_v	coefficient of consolidation
C_α	coefficient of secondary compression
D_n	particle size such that n % of the particles by weight are smaller than that size e.g. D_{10} , D_{15} , D_{30} , D_{60} and D_{85}

E	Young's modulus of elasticity
E'	drained (long term) Young's modulus of elasticity
E_{FDT}	flexible dilatometer modulus
E_{M}	Ménard pressuremeter modulus
E_{meas}	measured energy during calibration
E_{oed}	oedometer modulus
E_{PLT}	modulus from plate loading test
E_{r}	energy ratio ($= E_{\text{meas}} / E_{\text{theor}}$)
E_{theor}	theoretical energy
E_{u}	undrained Young's modulus of elasticity
E_0	initial Young's modulus of elasticity
E_{50}	Young's modulus of elasticity corresponding to 50 % of the maximum shear strength
I_{A}	activity index
I_{C}	consistency index
I_{D}	density index
I_{DMT}	material index from the flat dilatometer test
K_{DMT}	horizontal stress index from the flat dilatometer test
$\boxed{\text{AC1}} k$	coefficient of permeability $\boxed{\text{AC1}}$
I_{L}	liquidity index
I_{P}	plasticity index
k_{s}	coefficient of sub-grade reaction
m_{v}	coefficient of compressibility
N	number of blows per 300 mm penetration from the SPT
N_{k}	cone factor for CPT, (see equation (4.1))
N_{kt}	cone factor for CPTU, (see equation (4.2))
$N_{10\text{L}}$	number of blows per 10 cm penetration from the DPL
$N_{10\text{M}}$	number of blows per 10 cm penetration from the DPM
$N_{10\text{H}}$	number of blows per 10 cm penetration from the DPH
$N_{10\text{SA}}$	number of blows per 10 cm penetration from the DPSH-A
$N_{10\text{SB}}$	number of blows per 10 cm penetration from the DPSH-B
$N_{20\text{SA}}$	number of blows per 20 cm penetration from the DPSH-A
$N_{20\text{SB}}$	number of blows per 20 cm penetration from the DPSH-B
N_{60}	number of blows from the SPT corrected to energy losses
$(N_1)_{60}$	number of blows from the SPT corrected to energy losses and normalized for effective vertical overburden stress

p_{LM}	Ménard limit pressure
q_c	cone penetration resistance
q_t	cone penetration resistance corrected for pore water pressure effects
q_u	unconfined compressive strength
w_{opt}	optimum water content

Greek letters

α	correlation factor for E_{oed} and q_c , (see Equation (4.3))
φ	angle of shearing resistance
ϕ	angle of shearing resistance in terms of effective stress
μ	correction factor to derive c_u from c_{fv} , (see Equation (4.4))
$\rho_{d;max}$	maximum dry density
σ_C	unconfined compression strength of rock
σ_p	effective pre-consolidation pressure or effective vertical yield stress in situ
σ_T	tensile strength of rock
σ_{v0}	initial vertical total stress
σ'_{v0}	initial vertical effective stress
ν	Poisson's ratio

Abbreviations

CPT	electrical cone penetration test
CPTM	mechanical cone penetration test
CPTU	cone penetration test with pore water pressure measurement
DMT	flat dilatometer test
DP	dynamic probing
DPL	dynamic probing light
DPM	dynamic probing medium
DPH	dynamic probing heavy
DPSH-A	dynamic probing superheavy, type A
DPSH-B	dynamic probing superheavy, type B
FDP	full displacement pressuremeter
FDT	flexible dilatometer test
FVT	field vane test
MPM	Ménard pressuremeter

PBP	pre-bored pressuremeter
PLT	plate loading test
PMT	pressuremeter test
RDT	rock dilatometer test
SBP	self-boring pressuremeter
SDT	soil dilatometer test
SPT	standard penetration test
WST	weight sounding test

(2) For geotechnical calculations, the following units or their multiples are recommended:

– force	kN
– moment	kNm
– mass density	kg/m ³
– weight density	kN/m ³
– stress, pressure, strength and stiffness	kPa
– coefficient of permeability	m/s
– coefficient of consolidation	m ² /s

Section 2 Planning of ground investigations

2.1 Objectives

2.1.1 General

(1)P Geotechnical investigations shall be planned in such a way as to ensure that relevant geotechnical information and data are available at the various stages of the project. Geotechnical information shall be adequate to manage identified and anticipated project risks. For intermediate and final building stages, information and data shall be provided to cover risks of accidents, delays and damage.

(2) The aims of a geotechnical investigation are to establish the soil, rock and groundwater conditions, to determine the properties of the soil and rock, and to gather additional relevant knowledge about the site.

(3)P Careful collection, recording and interpretation of geotechnical information shall be made. This information shall include ground conditions, geology, geomorphology, seismicity and hydrology, as relevant. Indications of the variability of the ground shall be taken into account.

(4) Ground conditions which may influence the choice of geotechnical category should be determined as early as possible in the investigation.

NOTE As a result of the geotechnical investigations, it may be necessary to change the geotechnical category of the project (see 1.1.2 (4)).

(5) Geotechnical investigations should consist of ground investigations, and other investigations for the site, such as:

- the appraisal of existing constructions, e.g. buildings, bridges, tunnels, embankments and slopes;
- the history of development on and around the site.

(6) Before designing the investigation programme, the available information and documents should be evaluated in a desk study.

(7) Examples of information and documents that can be used are:

- topographical maps;
- old city maps describing the previous use of the site;
- geological maps and descriptions;
- engineering geological maps;
- hydrogeological maps and descriptions;
- geotechnical maps;
- aerial photos and previous photo interpretations;
- aero-geophysical investigations;
- previous investigations at the site and in the surroundings;
- previous experiences from the area;
- local climatic conditions.

(8) Ground investigations should consist of field investigations, laboratory testing, additional desk studies and controlling and monitoring, where appropriate.

(9)P Before the investigation programme has been drawn up the site shall be visually examined and the findings recorded and cross-checked against the information gathered by desk studies.

(10) The ground investigation programme should be reviewed as the results become available so that the initial assumptions can be checked. In particular:

- the number of investigation points should be extended if it is deemed necessary to obtain an accurate insight into the complexity and the variability of the ground at the site;
- the parameters obtained should be checked to see that they fit into a consistent behavioural pattern for soil or rock. If necessary additional testing should be specified;
- any limitations in the data, revealed according to EN 1997-1:2004, 3.4.3 (1) should be considered.

(11) Special attention should be paid to sites that have been previously used, where disturbance of the natural ground conditions may have taken place.

(12)P An appropriate quality assurance system shall be in place in the laboratory, in the field and in the engineering office, and quality control shall be exercised competently in all phases of the investigations and their evaluation.

2.1.2 Ground

(1)P Ground investigations shall provide a description of ground conditions relevant to the proposed works and establish a basis for the assessment of the geotechnical parameters relevant for all construction stages.

(2) The information obtained should enable assessment of the following aspects, if possible:

- the suitability of the site with respect to the proposed construction and the level of acceptable risks;
- the deformation of the ground caused by the structure or resulting from construction works, its spatial distribution and behaviour over time;
- the safety with respect to limit states (e.g. subsidence, ground heave, uplift, slippage of soil and rock masses, buckling of piles, etc.);
- the loads transmitted to the structure from the ground (e.g. lateral pressures on piles) and the extent to which they depend on its design and construction;
- the foundation methods (e.g. ground improvement, whether it's possible to excavate, driveability of piles, drainage);
- the sequence of foundation works;
- the effects of the structure and its use on the surroundings;
- any additional structural measures required (e.g. support of excavation, anchorage, sleeving of bored piles, removal of obstructions);
- the effects of construction work on the surroundings;
- the type and extent of ground contamination on, and in the vicinity of, the site;
- the effectiveness of measures taken to contain or remedy contamination.

2.1.3 Construction materials

(1)P Geotechnical investigations of soil and rock for use as construction materials shall provide a description of the materials to be used and shall establish their relevant parameters.

(2) The information obtained should enable an assessment of the following aspects:

- the suitability for the intended use;
- the extent of deposits;
- whether it is possible to extract and process the materials, and whether and how unsuitable material can be separated and disposed of;
- the prospective methods to improve soil and rock;
- the workability of soil and rock during construction and possible changes in their properties during transport, placement and further treatment;
- the effects of construction traffic and heavy loads on the ground;
- the prospective methods of dewatering and/or excavation, effects of precipitation, resistance to weathering, and susceptibility to shrinkage, swelling and disintegration.

2.1.4 Groundwater

(1)P Groundwater investigations shall provide all relevant information on groundwater needed for geotechnical design and construction.

(2) Groundwater investigations should provide, when appropriate, information on:

- the depth, thickness, extent and permeability of water-bearing strata in the ground, and joint systems in the rock;
- the elevation of the groundwater surface or piezometric surface of aquifers and their variation over time and actual groundwater levels including possible extreme levels and their periods of recurrence;
- the pore water pressure distribution;
- the chemical composition and temperature of groundwater.

(3) The information obtained should be sufficient to assess the following aspects, where relevant:

- the scope for and nature of groundwater-lowering work;
- possible harmful effects of the groundwater on excavations or on slopes (e.g. risk of hydraulic failure, excessive seepage pressure or erosion);
- any measures necessary to protect the structure (e.g. waterproofing, drainage and measures against aggressive water);
- the effects of groundwater lowering, desiccation, impounding etc. on the surroundings;
- the capacity of the ground to absorb water injected during construction work;
- whether it is possible to use local groundwater, given its chemical constitution, for construction purposes.

2.2 Sequence of ground investigations

(1)P The composition and the extent of the ground investigations shall be based on the anticipated type and design of the construction, e.g. type of foundation, improvement method or retaining structure, location and depth of the construction;

(2)P The results of the desk studies and the site inspection shall be considered when selecting the investigation methods and locating the various investigation points. Investigations shall be targeted at points representing the variation in ground conditions for soil, rock and groundwater.

(3) Ground investigations should normally be performed in phases depending on the questions raised during planning, design and construction of the actual project. The following phases are treated separately in Section 2:

- preliminary investigations for positioning and preliminary design of the structure (see 2.3);
- design investigations (see 2.4);
- controlling and monitoring (see 2.5).

NOTE The provisions in this document are based on the premise that the results from investigations recommended in one phase are available before the next phase is started.

(4) In cases where all investigations are performed at the same time, 2.3 and 2.4 should be considered simultaneously.

NOTE The different stages of ground investigations, including laboratory and field work and the process of evaluating soil and rock parameters, can follow the schemes in B.1 and B.2.

2.3 Preliminary investigations

(1) The preliminary investigations should be planned in such a way that adequate data are obtained, if relevant, to:

- assess the overall stability and general suitability of the site;
- assess the suitability of the site in comparison with alternative sites;
- assess the suitable positioning of the structure;
- evaluate the possible effects of the proposed works on surroundings, such as neighbouring buildings, structures and sites;
- identify borrow areas;
- consider the possible foundation methods and any ground improvements;
- plan the design and control investigations, including identification of the extent of ground which may have significant influence on the behaviour of the structure.

(2) A preliminary ground investigation should supply estimates of soil data concerning, if relevant:

- the type of soil or rock and their stratification;
- the groundwater table or pore pressure profile;
- the preliminary strength and deformation properties for soil and rock;
- the potential occurrence of contaminated ground or groundwater that might be hazardous to the durability of construction material.

2.4 Design investigations

2.4.1 Field investigations

2.4.1.1 General

(1)P In cases where the preliminary investigations do not provide the necessary information to assess the aspects mentioned in 2.3, complementary investigations shall be performed during the design investigation phase.

(2) If relevant, field investigations in the design phase should comprise:

- drilling and/or excavations (test pits including shafts and headings) for sampling;
- groundwater measurements;
- field tests.

(3) Examples of the various types of field investigations are:

- field testing (e.g. CPT, SPT, dynamic probing, WST, pressuremeter tests, dilatometer tests, plate load tests, field vane tests and permeability tests);
- soil and rock sampling for description of the soil or rock and laboratory tests;
- groundwater measurements to determine the groundwater table or the pore pressure profile and their fluctuations;
- geophysical investigations (e.g. seismic profiling, ground penetrating radar, resistivity measurements and down hole logging);
- large scale tests, for example to determine the bearing capacity or the behaviour directly on prototype elements, such as anchors.

(4) To develop strategies for planning field investigations, Table 2.1 can be used as a guide to the applicability of the field investigations covered in Sections 3 and 4.

NOTE See also B.2.

(5)P Where ground contamination or soil gas is expected, information shall be gathered from the relevant sources. This information shall be taken into account when planning the ground investigation.

Table 2.1 — Simplified overview of the applicability of field investigation methods^{a)} covered by Sections 3 and 4

Field investigation methods ^{a)}	Possibly obtainable results																				
	Sampling						Field tests												Groundwater measurements		
	Soil			Rock			CPT & CPTU	Pressuremeter ^{e)}	RDT	Flexible Dilatometer	SPT ^{d)}	DPL/DPM	DPH/DPSH	WST	FVT	DMT	PLT	Open system	Closed system		
	Category A	Category B	Category C	Category A	Category B	Category C															
Basic information																					
Type of soil	C1 F1	C1 F1	C2 F2	—	—	—	C2 F2	C3 F3	—	C3 F3	C2 F1	C3 F3	C3 F3	—	—	C2 F2	—	—	—		
Type of rock	—	—	—	R1	R1	R2	R3 ^{e)}	R3	R2		—	—	—	—	—	—	—	—	—		
Extension of layers ^{b)}	C1 F1	C1F1	C3 F3	R1	R1	R2	C1 F1	R3 C3 F3	R3	C3 F3	C2 F2	C1 F2	C1 F2	F2	—	C2 F1	—	—	—		
Groundwater level	—	—	—	—	—	—	C2	—	—	—	—	—	—	—	—	—	—	R2 C1 F2	R1 C1 F1		
Pore water pressure	—	—	—	—	—	—	C2 F2	F3	—	—	—	—	—	—	—	—	—	R2 C1 F2	R1 C1 F1		
Geotechnical properties																					
Particle size	C1 F1	C1 F1		R1	R1	R2	—	—	—	—	C2 F1	—	—	—	—	—	—	—	—		
Water content	C1 F1	C2 F1	C3 F3	R1	R1	—	—	—	—	—	C2 F2	—	—	—	—	—	—	—	—		
Atterberg limits	F1	F1	—	—	—	—	—	—	—	—	F2	—	—	—	—	—	—	—	—		
Density	C2 F1	C3 F3	—	R1	R1	—	C2 F2	—	—	—	C2F2	C2	C2	—	—	C2 F2	—	—	—		
Shear strength	C2 F1	—	—	R1	—	—	C2 F1	C1 F1	—	—	C2 F3	C2 F3	C2 F3	C2	F1	C2 F1	R2 C1 F1	—	—		
Compressibility	C2 F1	—	—	R1	—	—	C1 F2	C1 F1	R1	F1	C2 F2	C2 F2	C2 F2	C2	—	C2 F1	C1F1	—	—		
Permeability	C2 F1	—	—	R1	—	—	C3 F2	F3	—	—	—	—	—	—	—	—	—	C2 F3	C2 F2		
Chemical tests	C1 F1	C1 F1	—	R1	R1	—	—	—	—	—	C2 F2	—	—	—	—	—	—	—	—		
^{a)} see sections 3 and 4 for nomenclature				R1 High for rock		R2 Medium for rock					R3 Low for rock										
^{b)} in horizontal and vertical direction will depend on pressuremeter type assuming sample is retained				C1 High for coarse soil ^{*)}		C2 Medium for coarse soil					C3 Low for coarse soil										
^{c)} soft rock only				F1 High for fine soil ^{*)}		F2 Medium for fine soil					F3 Low for fine soil										
				— not applicable																	
				^{*)} main soil groups “coarse” and “fine” according to ISO 14688-1																	
Applicability:				NOTE Depending on the ground conditions (such as soil type, groundwater conditions) and the planned design, the selection of investigation methods will vary and may deviate from this table.																	

(6)P If ground contamination or soil gas is detected in the course of ground investigations, this shall be reported to the client and the responsible authorities.

2.4.1.2 Field investigation programme

(1)P The field investigation programme shall contain:

- a plan with the locations of the investigation points including the types of investigation;
- the depth of the investigations;
- the types of sample (category, etc.) to be taken including specifications for the number and depth at which they are to be taken;
- specifications on the groundwater measurement;
- the types of equipment to be used;
- the standards to be applied.

2.4.1.3 Locations and depths of the investigation points

(1)P The locations of investigation points and the depths of the investigations shall be selected on the basis of the preliminary investigations as a function of the geological conditions, the dimensions of the structure and the engineering problems involved.

(2) When selecting the locations of investigation points, the following should be observed:

- the investigation points should be arranged in such a pattern that the stratification can be assessed across the site;
- the investigation points for a building or structure should be placed at critical points relative to the shape, structural behaviour and expected load distribution (e.g. at the corners of the foundation area);
- for linear structures, investigation points should be arranged at adequate offsets to the centre line, depending on the overall width of the structure, such as an embankment footprint or a cutting;
- for structures on or near slopes and steps in the terrain (including excavations), investigation points should also be arranged outside the project area, these being located so that the stability of the slope or cut can be assessed. Where anchorages are installed, due consideration should be given to the likely stresses in their load transfer zone;
- the investigation points should be arranged so that they do not present a hazard to the structure, the construction work, or the surroundings (e.g. as a result of the changes they may cause to the ground and groundwater conditions);
- the area considered in the design investigations should extend into the neighbouring area to a distance where no harmful influence on the neighbouring area is expected.
- for groundwater measuring points, the possibility of using the equipment installed during the ground investigation for continued monitoring during and after the construction period should be considered.

(3) Where ground conditions are relatively uniform or the ground is known to have sufficient strength and stiffness properties, wider spacing or fewer investigation points may be applied. In either case, this choice should be justified by local experience.

(4)P In cases where more than one type of investigation is planned at a certain location (e.g. CPT and piston sampling), the investigation points shall be separated by an appropriate distance.

(5) In the case of a combination of, for example, CPTs and boreholes, the CPTs should be carried out prior to the boreholes. The minimum spacing should then be such that the borehole does not or is considered unlikely to encounter the CPT hole. If the drilling is conducted first, the CPT should be carried out at a horizontal separation of at least 2 m.

(6)P The depth of investigations shall be extended to all strata that will affect the project or are affected by the construction. For dams, weirs and excavations below groundwater level, and where dewatering work is involved, the depth of investigation shall also be selected as a function of the hydrogeological conditions. Slopes and steps in the terrain shall be explored to depths below any potential slip surface.

NOTE For the spacing of investigation points and investigation depths, the values given in B.3 can be used as guidance.

2.4.1.4 Sampling

(1)P The sampling categories (see 3.4.1 and 3.5.1), and the number of samples to be taken shall be based on:

- the aim of the ground investigation;
- the geology of the site;
- the complexity of the geotechnical structure.

(2)P For identification and classification of the ground, at least one borehole or trial pit with sampling shall be available. Samples shall be obtained from every separate ground layer influencing the behaviour of the structure.

(3) Sampling may be replaced by field tests if there is enough local experience to correlate the field tests with the ground conditions to ensure unambiguous interpretation of the results.

(4) Further details on sampling are given in Section 3.

2.4.1.5 Groundwater

(1)P Groundwater measurements shall be planned and carried out in accordance with 3.6.

2.4.2 Laboratory tests

2.4.2.1 General

(1) Prior to setting up a test programme, the expected stratigraphy at the site should be established and the strata relevant for design selected to enable the specification of the type and number of tests in each stratum. Stratum identification should be a function of the geotechnical problem, its complexity, the local geology and the required parameters for design.

2.4.2.2 Visual inspection and preliminary ground profile

(1) Samples and trial pits should be inspected visually and compared with field logs of the drillings so that the preliminary ground profile can be established. For soil samples, the visual inspection should be supported by simple manual tests to identify the soil and to give a first impression of its consistency and mechanical behaviour.

(2) If distinct and significant differences in the properties between different portions of one stratum are found, the preliminary soil profile should be further subdivided.

(3) Where practicable, the quality of the sample should be assessed before laboratory tests are performed. Quality classes for soil samples are defined in Table 3.1.

2.4.2.3 Test programme

(1)P The type of construction, the type of ground and stratigraphy and the geotechnical parameters needed for design calculations shall be taken into account when setting up the laboratory test programme.

(2) The laboratory test programme depends in part on whether comparable experience exists. The extent and quality of comparable experience for the specific soil or rock should be established. The results of field observations on neighbouring structures, when available, should also be used.

(3)P The tests shall be run on specimens representative of the relevant strata. Classification tests shall be used to check whether the samples and test specimens are representative.

NOTE This can be checked in an iterative way. In a first step, classification tests and strength index tests are performed on as many samples as possible to determine the variability of the index properties of a stratum. In a second step, an assessment of how representative the samples used for the strength and compressibility tests are of the stratum can be checked by comparing the results of the classification and strength index tests for the samples with all results from the classification and strength index tests for the stratum.

(4) The need for more advanced testing or additional site investigation as a function of the geotechnical aspects of the project, soil type, soil variability and computation model should be considered.

2.4.2.4 Number of tests

(1)P The necessary number of specimens to be tested shall be established depending on the homogeneity of the ground, the quality and amount of comparable experience with the ground and the geotechnical category of the problem.

(2) To allow for difficult soil, damaged specimens and other factors, additional test specimens should be made available, whenever possible.

(3) Depending on the test type, a minimum number of specimens should be investigated.

NOTE A recommended minimum number for some test types can be taken from the tables in Annexes L to W (except Annexes O and T). The annexes can also be used to check whether the extent of the testing was sufficient.

(4) The minimum number of tests may be reduced if the geotechnical design does not need to be optimised and uses conservative values of the soil parameters, or if comparable experience or combination with field information applies.

2.4.2.5 Classification tests

(1) Soil and rock classification tests should be performed to determine the composition and index properties of each stratum. The samples for the classification tests should be selected in such a way that the tests are approximately equally distributed over the complete area and the full depth of the strata relevant for design. Thus the results should give the range of index properties of the relevant layers.

(2) The results of the classification tests should be used to check if the extent of the investigations was sufficient or if a second investigation stage is needed.

(3) Suitable routine classification tests for ground samples with various degrees of disturbance are presented in Table 2.2. The routine tests are generally performed in all phases of the ground investigation (see 2.2 (3)).

2.4.2.6 Tests on samples

(1)P Samples for testing shall be selected so as to cover the range of index properties of each relevant stratum.

(2) For a fill or a stratum of sand or gravel, reconstituted specimens may be tested. Reconstituted specimens should have approximately the same composition, density and water content as in-situ material.

Table 2.2 — Soil classification tests

Parameter	Type of soil							
	Clayey soil			Silty soil			Sandy, gravelly soil	
	Type of specimen			Type of specimen			Type of specimen	
	Undis- turbed	Dis- turbed	Re- moul- ded	Undis- turbed	Dis- turbed	Re- moul- ded	Dis- turbed	Re- moul- ded
Geological description and soil classification	X	X	X	X	X	X	X	X
Water content	X	(X)	(X)	X	(X)	(X)	(X)	(X)
Bulk density	X	(X)	—	X	(X)	—	—	—
Minimum and maximum densities	—	—	—	(X)	(X)	(X)	X	X
Atterberg (consistency) limits	X	X	X	X	X	X	—	—
Particle size distribution	X	X	X	X	X	X	X	X
Undrained shear strength	X	—	—	(X)	—	—	—	—
Permeability	X	—	—	X	(X)	(X)	(X)	(X)
Sensitivity	X	—	—	—	—	—	—	—
X = normal to determine (X) = possible to determine, not necessarily representative — = not applicable NOTE For some types of soil, further tests may be considered, for example the determination of organic content, particle density and activity.								

(3) Laboratory tests to determine parameters for geotechnical calculations are given in Table 2.3.

(4) Suitable routine laboratory tests for rock samples giving the necessary basis for the description of the rock material are as follows:

- the geological classification;
- the density or bulk mass density (ρ) determination;
- the water content (w) determination;
- the porosity (n) determination;
- the uniaxial compression strength (σ_c) determination;
- the Young's modulus of elasticity (E) and Poisson's ratio (ν) determination;
- the point load strength index test ($I_{s,50}$).

(5) The classification of rock core samples will normally comprise a geological description, the core recovery, the Rock Quality Designation (RQD), the degrees of induration, fracture log, weathering and fissuring. In addition to the routine tests mentioned in 2.4.2.6 (4) for rocks, other tests may be selected for different purposes, e.g. density of grains determination, wave velocity determination, Brazilian tests, shear strength of rock and joints determination, slake durability tests, swelling tests and abrasion tests.

(6) The properties of the rock mass including the layering and fissuring or discontinuities may be investigated indirectly by compression and shear strength tests along joints. In weak rocks, complementary tests in the field or large-scale laboratory tests on block samples may be made.

Table 2.3 — Laboratory tests for the determination of geotechnical parameters

Geotechnical parameter	Type of soil					
	Gravel	Sand	Silt	NC clay	OC clay	Peat organic clay
Oedometer modulus (E_{oed}); compression index (C_c); [one-dimensional compressibility]	(OED) (TX)	(OED) (TX)	OED (TX)	OED (TX)	OED (TX)	OED (TX)
Young's modulus (E); Shear modulus (G)	TX	TX	TX	TX	TX	TX
Drained (effective) shear strength (c'), (ϕ')	TX SB	TX SB	TX SB	TX SB	TX SB	TX SB
Residual shear strength (c'_R), (ϕ'_R)	RS (SB)	RS (SB)	RS (SB)	RS (SB)	RS (SB)	RS (SB)
Undrained shear strength (c_u)	—	—	TX DSS SIT	TX DSS (SB) SIT	TX DSS (SB) SIT	TX DSS (SB) SIT
Bulk density (ρ)	BDD	BDD	BDD	BDD	BDD	BDD
Coefficient of consolidation (c_v)			OED TX	OED TX	OED TX	OED TX
Permeability (k)	TXCH PSA	TXCH PSA	PTC TXCH (PTF)	TXCH (PTF) (OED)	TXCH (PTF) (OED)	TXCH (PTF) (OED)
— = not applicable () = partially applicable only; for details, see Section 5. Abbreviations of laboratory tests: BDD Bulk density determination DSS Direct simple shear test OED Oedometer test PTF Permeability test in the falling head permeameter PTC Permeability test in the constant head permeameter RS Ring shear (Ring shear box test) SB Translational shear box test SIT Strength index tests (normally performed in the preliminary phase only) PSA Particle size analysis TX Triaxial test TXCH Permeability constant head test in the triaxial cell (or flexible wall permeameter)						

2.5 Controlling and monitoring

(1)P A number of checks and additional tests shall be made during the construction and execution of the project, when relevant, in order to check that the ground conditions agree with

those determined in the design investigations and that the properties of the delivered construction materials and the construction works correspond to those presumed or specified.

NOTE See also EN 1997-1:2004, Section 4.

(2)P The following control measures shall be applied:

- check of ground profile when excavating;
- inspection of the bottom of the excavation.

(3) The following general control measures may be applied:

- measurements of groundwater level or pore pressures and their fluctuations;
- measurements of the behaviour of neighbouring constructions, services or civil engineering works;
- measurements of the behaviour of the actual construction.

NOTE Controlling and monitoring is of prime importance when the observational method is used (see EN 1997-1:2004, 2.7).

(4)P The results of the control measures shall be compiled, reported and checked against the design requirements. Decisions shall be taken based on these findings.

Section 3 Soil and rock sampling and groundwater measurements

3.1 General

(1)P Sampling of soils and rocks by drilling and excavations and groundwater measurements shall be conducted so comprehensively that the necessary geotechnical design data are obtained.

3.2 Sampling by drilling

(1)P The drilling equipment shall be selected according to:

- the sampling categories required, as defined in 3.4.1 and 3.5.1;
- the depth to be reached and the required diameter of the sample;
- the functions required from the drilling rig, e.g. recording of the drilling parameters, automatic or manual adjustment.

(2)P The requirements of EN ISO 22475-1 shall be followed.

3.3 Sampling by excavation

(1)P If samples are recovered from trial pits, headings or shafts, the requirements of EN ISO 22475-1 shall be followed.

3.4 Soil sampling

3.4.1 Categories of sampling methods and laboratory quality classes of samples

(1)P Samples shall contain all the mineral constituents of the strata from which they have been taken. They shall not be contaminated by any material from other strata or from additives used during the sampling procedure.

(2)P Three sampling method categories shall be considered (EN ISO 22475-1), depending on the desired sample quality as follows (for sample quality see Table 3.1):

- category A sampling methods: samples of quality class 1 to 5 can be obtained;
- category B sampling methods: samples of quality class 3 to 5 can be obtained;
- category C sampling methods: only samples of quality class 5 can be obtained.

(3) Samples of quality classes 1 or 2 can only be obtained by using category A sampling methods. The intention is to obtain samples of quality classes 1 or 2, in which no or only slight disturbance of the soil structure has occurred during the sampling procedure or in the handling of the samples. The water content and the void ratio of the soil correspond to those in-situ. No change in constituents or in chemical composition of the soil has occurred. Certain unforeseen circumstances such as variations in geological strata may lead to lower sample quality classes being obtained.

(4) Using category B sampling methods will preclude achieving samples of quality classes better than 3. The intention is to obtain samples that contain all the constituents of the in-situ soil in their original proportions and for the soil to retain its natural water content. The general arrangement of the different soil layers or components can be identified. The structure of the soil has been

disturbed. Certain unforeseen circumstances such as variation in geological strata may lead to lower sample quality classes being obtained.

(5) By using category C sampling methods, samples of quality classes better than 5 cannot be obtained. The soil structure in the sample has been totally changed. The general arrangement of the different soil layers or components has been modified so that the in-situ layers cannot be identified accurately. The water content of the sample needs not represent the natural water content of the soil layer sampled.

(6)P Soil samples for laboratory tests are divided in five quality classes with respect to the soil properties that are assumed to remain unchanged during sampling and handling, transport and storage. The classes are described in Table 3.1, together with the sampling category to be used.

Table 3.1 — Quality classes of soil samples for laboratory testing and sampling categories to be used

Soil properties / quality class	1	2	3	4	5
Unchanged soil properties					
particle size	*	*	*	*	
water content	*	*	*		
density, density index, permeability	*	*			
compressibility, shear strength	*				
Properties that can be determined					
sequence of layers	*	*	*	*	*
boundaries of strata – broad	*	*	*	*	
boundaries of strata – fine	*	*			
Atterberg limits, particle density, organic content	*	*	*	*	
water content	*	*	*		
density, density index, porosity, permeability	*	*			
compressibility, shear strength	*				
Sampling category according to EN ISO 22475-1	A				
			B		
					C

3.4.2 Soil identification

(1)P Soil identification, based on the examination of the samples recovered, shall conform to EN ISO 14688-1.

3.4.3 Planning of soil sampling

(1)P The quality class and number of samples to be recovered shall be based on the aims of the soil investigations, the geology of the site, and the complexity of the geotechnical structure and of the construction to be designed.

(2) Two different strategies may be followed for sampling by drilling.

- Drilling aimed at recovering the complete soil column, with samples obtained by the drilling tools down the borehole and by special samplers at selected depths at the borehole bottom.

- Drilling to recover samples only at specific predetermined elevations, e.g. by separately conducted penetration tests.

(3)P The sampling categories shall be selected considering the desired laboratory quality classes, as detailed in Table 3.1, the expected soil types, and groundwater conditions.

(4)P The requirements of EN ISO 22475-1 shall be followed, for the selection of the drilling or excavation methods and sampling equipment adequate to the soil sampling category prescribed.

NOTE The recovery of completely undisturbed samples is practically impossible due to, among other factors, the mechanical disturbance caused by the sampling operations and to the unavoidable stress release when recovering the sample. The effect of these factors on the degree of disturbance depends on the sampling category used and the types of soil being sampled. The type of soil being sampled has a decisive influence on the degree of disturbance of samples obtained by the same sampling methods. Thus very sensitive soils are prone to disturbance, while less sensitive soils, such as most stiff clays, may require less restrictive methods of sampling for obtaining fairly undisturbed samples. On the other hand, each problem requires a different degree of accuracy for the soil parameters to be used. As a consequence, when preparing a sampling programme, the factors mentioned above should be considered in order to decide the degree of disturbance that can be accepted and therefore the sampling methods to be required.

(5) For a given project, specific sampling equipment and methods may be required within the sampling categories defined in 3.4.1. For instance, this is the case when the deformation moduli (stiffness) at small strains have to be determined in undisturbed samples.

(6)P The dimensions of the samples to be recovered shall be in accordance with the type of soil and the type and number of tests to be performed.

NOTE See Section 5 and Annexes L, M, N, P, Q, R and S.

(7) Samples should be taken at any change of stratum and at a specified spacing, usually not larger than 3 m. In inhomogeneous soil, or if a detailed definition of the ground conditions is required, continuous sampling by drilling should be carried out or samples recovered at very short intervals.

3.4.4 Handling, transport and storing of samples

(1)P Handling, transport and storing of samples shall be carried out in accordance with EN ISO 22475-1.

NOTE For handling and storing in the laboratory, see Section 5.

3.5 Rock sampling

3.5.1 Categories of sampling methods

(1)P Samples shall contain all the mineral constituents of the strata from which they have been taken. They shall not be contaminated by any material from other strata or from additives used during the sampling procedure.

(2)P The discontinuities and corresponding infilling materials existing in the rock mass often control the strength and deformation characteristics of the material as a whole. Therefore, they shall be defined as closely as possible during the sampling operations, if such properties have to be determined.

(3)P Three sampling method categories shall be considered (see EN ISO 22475-1), depending on the quality of sample:

- category A sampling methods;
- category B sampling methods;
- category C sampling methods.

(4) By using category A sampling methods, the intention is to obtain samples in which no or only slight disturbance of the rock structure has occurred during the sampling procedure or in handling of the samples. The strength and deformation properties, water content, density, porosity and the permeability of the rock sample correspond to the in-situ values. No change in constituents or in chemical composition of the rock mass has occurred. Certain unforeseen circumstances such as variations of the geological strata may lead to lower sample quality being obtained.

(5) By using category B sampling methods, the intention is to obtain samples that contain all the constituents of the in-situ rock mass in their original proportions and with the rock pieces retaining their strength and deformation properties, water content, density and porosity. By using category B sampling methods, the general arrangement of discontinuities in the rock mass can be identified. The structure of the rock mass has been disturbed and thereby the strength and deformation properties, water content, density, porosity and permeability for the rock mass itself. Certain unforeseen circumstances such as variations of the geological strata can lead to lower sample quality being obtained.

(6) Category C sampling methods lead to the structure of the rock mass and its discontinuities being totally changed. The rock material may have been crushed. Some changes in constituents or in chemical composition of the rock material can occur. The rock type and its matrix, texture and fabric can be identified.

3.5.2 Rock identification

(1)P Visual rock identification shall be based on examination of the rock masses and samples including all observations of decomposition and discontinuities. The identification shall conform to EN ISO 14689-1.

(2)P Weathering classification shall be related to the geological processes and shall cover the grades between fresh rock and rock decomposed into soil. The classification shall conform to 4.2.4 and 4.3.4 of EN ISO 14689-1:2003.

(3)P Discontinuities such as bedding planes, joints, fissures, cleavages and faults shall be quantified with respect to pattern, spacing and inclination using unambiguous terms. The quantification shall conform to 4.3.3 of EN ISO 14689-1:2003.

(4)P Rock quality designation (RQD), total core recovery (TCR), and solid core recovery (SCR), as defined by EN ISO 22475-1, shall be determined.

3.5.3 Planning of rock sampling

(1)P The characteristics and number of samples to be recovered shall be based on the aim of the site investigations, the geology of the area and the complexity of the geotechnical structure and of the construction to be designed.

(2)P The category of the sampling methods to be prescribed shall be selected according to the rock characteristics to be preserved, as detailed in 3.5.1, and the expected rock and groundwater conditions.

(3)P The requirements of EN ISO 22475-1 shall be followed for the selection of the drilling or excavation methods and sampling equipment.

(4) For a given project, specific sampling equipment and methods may be required within the rock sampling categories defined in 3.5.1.

3.5.4 Handling, transport and storing of samples

(1)P After sampling and visual inspection has taken place, the obtained cores shall be preserved, handled and stored according to EN ISO 22475-1.

3.6 Groundwater measurements in soils and rocks

3.6.1 General

(1)P Groundwater measurements shall conform to 2.1.4.

(2)P The determination of the groundwater table or pore water pressures in soils and rocks shall be made by installing open or closed groundwater measuring systems into the ground.

NOTE Subclause 3.6 applies to the measurement of positive pore water pressures relative to the atmospheric pressure. Measurements of negative pore water pressures are not considered.

3.6.2 Planning and execution of the measurements

(1)P When relevant, groundwater measurements and sampling shall be conducted in accordance with EN ISO 22475-1.

(2)P The type of equipment to be used for groundwater measurements shall be selected according to the type and permeability of ground, the purpose of the measurements, the required observation time, the expected groundwater fluctuations and the response time of the equipment and ground.

(3) There are two main methods for measuring the groundwater pressure: open systems and closed systems. In open systems the piezometric groundwater head is measured by an observation well, usually provided with an open pipe. In closed systems the groundwater pressure at the selected point is directly measured by a pressure transducer.

(4) Open systems are best suited for soils and rock with a relatively high permeability (aquifers and aquitards), e.g. sand, gravel or highly fissured rock. With soils and rocks of low permeability they may lead to erroneous interpretations, due to the time lag for filling and emptying the pressure pipe. The use of filter tips connected to a small diameter hose in open systems, decreases the time lag.

(5) Closed systems can be used in all types of soil or rock. They should be used in very low permeability soils and rocks (aquicludes), e.g. clay or low fissured rock. Closed systems are also recommended when dealing with high artesian water pressure.

- (6)P When very short- term variations or fast pore water fluctuations are to be monitored, continuous recording shall be used by means of transducers and data loggers, with any types of soils and rocks.
- (7)P In cases where open water is situated within or close to the investigation area, the water level shall be considered in the interpretation of the groundwater measurements. The water level in wells, the occurrence of springs and artesian water shall also be noted.
- (8)P The number, location and depth of the measuring stations shall be chosen considering the purpose of the measurements, the topography, the stratigraphy and the soil conditions, especially the permeability of the ground or identified aquifers.
- (9)P For monitoring projects e.g. groundwater lowering, excavations, fillings and tunnels, the location shall be chosen with respect to the expected changes to be monitored.
- (10) For reference purposes, measurement of the natural fluctuations in groundwater should be made, if possible, outside the area affected by the actual project.
- (11)P In order to obtain measurements reflecting the pore pressure at the intended point in a soil or rock layer, provisions shall be made, according to EN ISO 22475-1, to ensure that the measuring point is adequately sealed off with regard to other layers or aquifers.
- (12)P The number and frequency of readings and the length of the measuring period for a given project shall be planned considering the purpose of the measurements and the stabilisation period.
- (13) The criteria adopted should be adjusted after an initial period of time, according to the actual variations of the readings being observed.
- (14)P If it is intended to assess groundwater fluctuations, measurements shall be taken at intervals smaller than the natural fluctuations to be characterised and over a long period of time.
- (15) During the drilling process, the observation of the water level at the end of the day and the start of the following day (before the drilling is resumed) is a good indication of the groundwater conditions and should be recorded. Any sudden inflow or loss of water during drilling should also be recorded, since it can provide additional useful information.
- (16) During the first phases of site investigations, some of the boreholes may be equipped with open perforated pipes protected with filters. The water level readings obtained during the following days yield a preliminary indication of groundwater conditions, but are subject to the limitations mentioned in 3.6.2 (4). The dangers associated with the connection of different aquifers should be taken into account, as well as any relevant environmental regulations.

3.6.3 Evaluation of results of groundwater measurements

- (1)P The evaluation of groundwater measurements shall take into account the geological and geotechnical conditions of the site, the accuracy of individual measurements, the fluctuations of pore water pressures with time, the duration of the observation period, the season of measurements and the climatic conditions during and prior to that period.

(2)P The evaluated results of groundwater measurements shall comprise the observed maximum and minimum elevations of the water table, or pore pressures and the corresponding measuring period.

(3)P If applicable, upper and lower bounds for both extreme and normal circumstances shall be derived from the measured values, by adding or subtracting the expected fluctuations or a reduced part of them, to the respective extreme or normal circumstances. The frequent lack of reliable data for extended periods of time of this type of measurements will necessitate the derived values being a cautious estimate based on the limited available information.

(4) The need for making further measurements or installing additional measuring stations should be assessed during the field investigations and in the ground investigation report.

NOTE In Annex C, an example is presented of a statistical method to evaluate the groundwater conditions, when long term measurements in a reference pipe in the region are available and a short measuring period on the actual site has been carried out.

Section 4 Field tests in soil and rock

4.1 General

(1)P When field tests are conducted, they shall be linked to sampling by excavating and drilling, in order to collect information on the ground stratification and to obtain geotechnical parameters or direct input for design methods (see also EN 1997-1:2004, 3.3).

(2)P Field tests shall be planned considering the following general points (see also Section 2):

- geology/stratification of the ground;
- type of structure, the possible foundation and the anticipated work during the construction;
- type of geotechnical parameter required;
- design method to be adopted.

(3) The tests or combinations thereof should be selected from the following types, contained in the Parts of EN ISO 22476 and covered in this Section:

- cone penetration test;
- pressuremeter and dilatometer tests;
- standard penetration test;
- dynamic probing;
- weight sounding test;
- field vane test;
- flat dilatometer test;
- plate loading test.

Table 2.1 gives a broad overview for the applicability of the tests in different ground conditions.

(4) Other complementary internationally recognised investigation methods, for instance geophysical methods, may be used.

4.2 General requirements

4.2.1 Planning a specific test programme

(1)P In addition to the recommendations given in 2.3 and the requirements given in 2.4 and 4.1

(2), the following information shall be established:

- ground profile to be expected;
- desired total depth of investigation;
- elevation of ground surface and if applicable groundwater level.

(2)P When designing the ground investigation programme, the selection of the type of field tests and of the test equipment shall aim at obtaining the best technical and economical solution for the intended purpose.

NOTE see also Table 2.1 and B.2.

4.2.2 Execution

- AC1** (1)P For the tests covered in this Section, equipment and procedures shall correspond to the requirements in EN ISO 22476-1 to EN ISO 22476-9, EN ISO 22476-12 and EN ISO 22476-13. **AC1**

NOTE Further information on a procedure, presentation and evaluation of the weight sounding test and the flat dilatometer test can be found in CEN ISO/TS 22476-10 and CEN ISO/TS 22476-11 respectively.

(2)P If the results obtained during the ongoing investigation do not correspond to the initial information (see Section 2) about the test site and/or the aim of the investigation, additional measures shall be considered such as:

- additional tests;
- changing to different test methods.

(3) If the desired investigation depth is not reached, the client should be informed immediately.

4.2.3 Evaluation

(1)P In evaluating the field test results, especially in the context of deriving geotechnical parameters/coefficients from the results, any additional information about the ground conditions shall be considered.

(2)P Results from any sampling by drilling and excavations according to Section 3 shall be available and shall be used in evaluating the test results.

(3)P In evaluating the test results, the possible geotechnical and equipment influences on the measured parameters shall be considered. When a soil or rock formation exhibits anisotropy, attention shall be paid to the axis of loading with respect to the anisotropy.

(4)P If correlations are used to derive geotechnical parameters/coefficients, their suitability shall be considered for each particular project.

(5)P When using Annexes D to K, it shall be ensured that the ground conditions of the site under investigation (soil type, uniformity coefficient, consistency index etc.) are compatible with the boundary conditions given for the correlation. Local experience shall be used for confirmation, if available.

NOTE 1 Annexes D to K give examples of correlations for the establishment of derived values and for the application of test values to design methods.

NOTE 2 X.3 contains examples of correlations for the establishment of derived values from test results and also the use of test results directly in design.

AC1 4.3 Cone penetration and piezocone penetration tests (CPT, CPTU, CPTM) AC1

4.3.1 Objectives

(1) The objective of the cone penetration test (CPT) is to determine the resistance of soil and soft rock to the penetration of a cone and the local friction on a sleeve.

(2)P The CPT consists of pushing a cone penetrometer vertically into the soil using a series of push rods. The cone penetrometer shall be pushed into the soil at a constant rate of penetration. The cone penetrometer comprises the cone and if appropriate a cylindrical shaft or friction sleeve. The penetration resistance of the cone (q_c) as well as, if appropriate, the local friction on the friction sleeve shall be measured.

(3)P For electrical CPTs, all measurements shall be made by sensors contained in the cone penetrometer.

(4) For mechanical CPTs, the measurements are generally made remotely.

(5) The piezocone penetration test, CPTU, is an electrical CPT, which includes additional instrumentation to measure the pore water pressure during penetration at the level of the base of the cone.

(6) The CPTU results should be used mainly for the determination of a soil profile together with results from sampling by drilling and excavations according to Section 3 or in comparison with other field tests.

(7) The results may also be used for the determination of geotechnical parameters such as the strength and deformation properties of soil and soft rock provided penetration is possible, and for direct input to design methods, generally in coarse and fine soil but also possibly in other deposits.

(8) The results may also be used to determine the length of piles and their compressive or tensile resistance or the dimensions of shallow foundations.

4.3.2 Specific requirements

AC1 (1)P The tests shall be carried out and reported in accordance with a method that conforms to the requirements given in EN ISO 22476-1 for the electrical CPT and CPTU, or EN ISO 22476-12 for the CPTM. **AC1**

(2)P When planning the test programme for a project, the following items shall be decided in addition to the requirements given in 4.2.1:

- type of required cone penetration test according to EN ISO 22476-1 or EN ISO 22476-12;
- depth and duration of pore pressure dissipation tests, if applicable.

(3)P Any deviation from the requirements given in EN ISO 22476-1 or EN ISO 22476-12 shall be justified and reported. In particular, any influence on the results shall be commented upon.

4.3.3 Evaluation of test results

(1)P In addition to the requirements given in 4.2, the field and test reports according to EN ISO 22476-1 or EN ISO 22476-12 shall be used for evaluation purposes.

(2)P Possible geotechnical influences on the penetration resistance shall be considered in evaluating the test results, e.g. in clays, the cone penetration resistance corrected for pore water pressure effects, (q_c), should be used in evaluation.

4.3.4 Use of test results and derived values

4.3.4.1 Bearing resistance and settlement of spread foundations

(1)P If the bearing resistance or the settlement of a spread foundation is derived from CPT results, either a semi-empirical or an analytical design method shall be used.

NOTE See, for example, EN 1997-1:2004, Annex D or F.

(2)P If a semi-empirical method is used, all the features of the method shall be taken into account.

NOTE If, for instance, the semi-empirical method to determine the settlement of spread foundations from CPT results is used (see D.3), only Young's modulus of elasticity derived from q_c is applied in this particular method as shown in the example.

(3) If the sample analytical method for bearing resistance of Annex D in EN 1997-1:2004 is used, the undrained shear strength of fine soil, (c_u) may be determined for a CPT from:

$$c_u = \frac{q_c - \sigma_{v0}}{N_k} \quad (4.1)$$

Or, in the case of a CPTU, from:

$$c_u = \frac{q_t - \sigma_{v0}}{N_{kt}} \quad (4.2)$$

where

q_c is the cone penetration resistance
 q_t is the cone penetration resistance corrected for pore water pressure effects;
 N_k and N_{kt} are coefficients estimated from local experience or reliable correlations
 σ_{v0} is the initial total vertical overburden stress at the depth under consideration;

(4) If the sample analytical method for bearing resistance calculation of Annex D of EN 1997-1:2004 is used, the angle of shearing resistance (ϕ') may be determined from the cone resistance (q_c), on the basis of local experience, taking into account depth effects, when relevant.

NOTE 1 An example of ranges of values to estimate ϕ' from q_c for quartz and feldspar sands is given in D.1, for estimating the bearing resistance of spread foundations when depth effects do not need to be taken into account.

NOTE 2 In addition, an example for a correlation between ϕ' and q_c for poorly-graded sands is given in D.2. The correlation given in D.2 should be considered as giving a conservative estimate.

(5) More elaborate methods may also be used for determining ϕ' from q_c , taking into account the effective vertical stress, the compressibility, and the over-consolidation ratio.

(6) If an adjusted elasticity method is used for calculating settlements of spread foundations from CPT results, the correlation between cone resistance (q_c) and the drained (long term) Young's modulus of elasticity (E') depends on the nature of the method: the semi-empirical elasticity method, or the theoretical elastic method.

NOTE An adjusted elasticity method is given in EN 1997-1:2004, Annex F.

(7) Semi-empirical methods may be used for calculating settlements in coarse soil.

NOTE An example is given in D.3.

(8) When a theoretical elastic method is used, the drained (long term) Young's modulus of elasticity (E') may be determined from cone resistance (q_c), on the basis of local experience.

NOTE An example of sample values for quartz and feldspar sands is given in D.1 to estimate a value of E' from q_c .

(9) Correlations between the oedometer modulus (E_{oed}) and the cone resistance (q_c) may also be used when calculating settlements of spread foundations. The following relationship between E_{oed} and q_c is often adopted:

$$E_{\text{oed}} = \alpha \times q_c \quad (4.3)$$

where

α is a correlation factor depending on local experience.

NOTE An example of a correlation is given in D.4.

(10) When a theoretical elastic method is used to calculate the settlements of spread foundations, a stress dependant oedometer modulus (E_{oed}), based on q_c , may be used.

NOTE 1 For examples of theoretical elastic methods, see EN 1997-1:2004, Annex F.

NOTE 2 Examples of correlations between q_c and E_{oed} are given in D.5. The correlations given in D.5 should be considered as conservative estimates.

4.3.4.2 Pile bearing resistance

(1)P If the ultimate compressive or tensile resistance of piles according to EN 1997-1:2004, 7.6.2.3 or 7.6.3.3 is derived from CPT results, calculation rules based on locally established correlations between the results of static load tests and CPT results shall be used.

NOTE 1 An example for such correlations for coarse soil is shown in D.6.

NOTE 2 An example is given for the assessment of the compressive resistance of a single pile on the basis of q_c -values from a CPT in D.7.

4.4 Pressuremeter tests (PMT)

4.4.1 Objectives

(1) The objective of the pressuremeter test is to measure in-situ the deformation of soil and soft rock caused by the expansion of a cylindrical flexible membrane under pressure.

(2)P The test consists of inserting a probe containing a cylindrical flexible membrane into the ground either into a pre-formed borehole, or by self-boring or by full displacement pushing. Once at a predetermined depth the membrane is expanded under pressure and readings of pressure and expansion are recorded until a maximum expansion for the particular device is reached.

NOTE Expansion is measured from radial displacement, or calculated from volume change of the cylindrical membrane.

(3) The test should be used to derive strength and/or deformation parameters of the ground or specific pressuremeter parameters.

(4) The results may be used to derive stress-strain curves in fine soil and soft rock.

4.4.2 Specific requirements

(1)P When planning a test programme for a project the type of pressuremeter to be used shall be specified.

(2)P There are four different types of apparatus generally available, for which the corresponding standards shall be used:

- pre-bored pressuremeters (PBP), e.g. the flexible dilatometer test (FDT), according to EN-ISO 22476-5;
- the Ménard pressuremeter (MPM), a specific form of the PBP, according to EN ISO 22476-4;
- the self-boring pressuremeter (SBP), according to EN ISO 22476-6;
- the full-displacement pressuremeter (FDP), according to EN ISO 22476-8.

NOTE The PBP and the MPM are lowered into a test hole created specifically for the pressuremeter test. The SBP is drilled into the ground using an integral cutting head at its lower end such that the probe replaces the material it removes thereby creating its own test hole. The FDP is usually pushed into the ground with an integral cone at its lower end, thereby creating its own test hole. The MPM may in some instances be pushed or driven into the ground. PBP, SBP and FDP probes may take a number of forms, in accordance with the type of installation and measuring systems.

(3) Two different basic test procedures may be used:

- a procedure to obtain a pressuremeter modulus, (E_M), and limit pressure, (p_{LM}), that may be used in design procedures formulated for the Ménard pressuremeter; and
- a procedure to obtain other stiffness and strength parameters.

(4)P The tests shall be carried out and reported in accordance with a test method that conforms to the requirements for the particular instrument type to be used,
 (see 4.4.2 (2)P).

(5)P Any deviations from the requirements given in the corresponding standard shall be justified and in particular their influence on the results shall be commented upon.

4.4.3 Evaluation of test results

(1)P If necessary, the applied pressure shall be corrected for membrane stiffness to obtain the true pressure applied to the cylindrical ground contact surface around the probe.

(2)P If a radial displacement type pressuremeter is used, the displacement readings shall be converted to cavity strain and, if testing weak rock, corrected for membrane compression and thinning.

(3)P If a volume displacement type pressuremeter is used (e.g. MPM), the volume reading shall be corrected for system expansion.

(4)P In addition to the requirements given in 4.2, the field and test reports according to EN ISO 22476-4 EN ISO 22476-5 EN ISO 22476- 6 and EN ISO 22476-8 for the specific test type shall be used for the basis of any further evaluation.

(5) In addition to the plots required by the individual equipment test standard, the list of additional plots in Table 4.1 should be considered.

Table 4.1 — A list of additional plots

Probe	Ground type	Abscissa	Ordinate
Radial displacement type			
Self-bored, pushed in	All	Cavity strain for each arm	Applied pressure
Pre-bored	All	Cavity strain for each pair of arms	Applied pressure
Self bored	All	initial cavity strain for each arm	Applied pressure
All	All	Cavity strain for unload-reload cycle for each arm	Applied pressure
All	Clay	Logarithm of cavity strain for each arm	Applied pressure
All	Sands	Natural logarithm of current cavity strain for each arm	Natural logarithm of effective applied pressure
Volume displacement type (except MPM) ^a			
Pre-bored	All	Volume change	Applied pressure
Pre-bored	All	Rate of change of volume	Applied pressure
^a For MPM tests, the pressure is plotted as abscissa and the volume change as ordinate.			